2006-271: TEACHING PLANT DESIGN/MATERIAL HANDLING BY PROJECT-BASED APPROACH

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Abstract

At our institute, instructors of MFG 407 (*Plant Design/Material Handling*) have tried to teach this senior-level course by adopting a project-based approach. In the course, the students formed project teams and pursued their own interests in identifying real-world problems that they wanted to solve in sponsored projects. With the instructors' facilitation, the students were self-motivated in learning. The endeavors to establish the project-based environment produced encouraging results. Students not only gained theoretical knowledge and hands-on skills but also acquired confidence to meet the challenges in their future professional development in manufacturing areas. This paper explains the experiences of MFG 407 instructors regarding how to set up a project-based learning environment in the engineering course.

Keywords

Engineering education; Facilities Planning; Material Handling; Project-based learning.

Introduction

Project-based learning (PBL) is any learning environment in which the problem drives the learning [1]. PBL emphasizes learning activities that are interdisciplinary, student-centered, and integrated with real-world issues and practices [2]. It is currently the most-favored pedagogical model for teaching design [3] and has the following significant benefits as far as learning, work habits, problem-solving capabilities, and self-esteem are concerned [2, 4-7]:

- PBL is learner-centered. It motivates students to pursue their own interests and make decisions about how to solve the complex problems in an integrated problem-solving environment.
- PBL increases students' confidence in their learning capabilities. It encourages the students to dig more deeply into a topic and expand their interests.
- PBL is suitable for introductory science and engineering classes.
- PBL provides opportunities for students to learn other skills desired by today's employers, such as collaboration with others, commitment to quality, timeliness, and continuous improvement.
- PBL helps the students to possess an interest in lifelong learning.

At our institute, MFG 407 (*Plant Design/Material Handling*) is a senior engineering course offered to manufacturing and mechanical engineering students. The instructors of MFG 407 have tried to teach this course by adopting a project-based approach. Basically, the process to build a project-based learning environment in MFG 407 follows the pattern proposed by D. R. Woods, as illustrated in Figure 1.

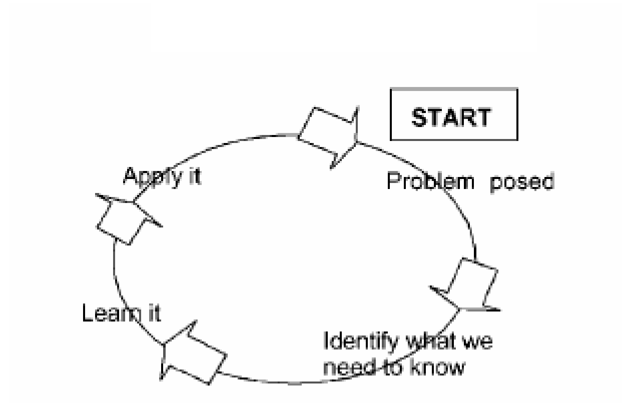


Figure 1. Project-based learning process [7].

There were seven students in MFG 407 class this past fall term. With the instructors' facilitation, the students were self-motivated in learning. They formed two project teams (3 people and 4 people on a team respectively) and pursued their own interests in identifying real-world problems that they wanted to solve.

Building a project-based learning environment

Based on their related research [8] and extensive industrial exposure, instructors of MFG 407 designed the project-based learning environment in this sequence:

1. Problem posing and selection of projects
2. In-class learning with the help of multimedia technologies
3. Enrichment of learning by plant tours
4. Project management and assessment
5. Publication of technical papers based on projects

The above five steps reflect the project-based learning process with a different focus in each step. The first step identifies what problems the projects need to solve and what knowledge is necessary. The second and third steps ensure that students can obtain sufficient knowledge required for their projects. The fourth step focuses on improving the students' self-management so that they can fully integrate the course materials into their projects. The fifth step is to stimulate the students to dig deeper into the project problems and help them to develop life-long learning interests.

Problem posing and project selection

In this project-based learning environment, student teams are presented with complex problems that focus and act as catalysts for what they need to learn [6]. From the first day of class, students were encouraged to seek problems related to facilities planning and material handling. After identifying the problem, the student talked with the instructors to see if a project could be established. The instructors set forth several criteria to define a feasible project. The projects should aim at solving a real-world problem. The students should have the opportunity to use fundamental methodologies of facilities planning and material handling to solve the problem. The project location should be close to campus so that the students do not need to travel. The projects should be finished within the academic term.

Under the guidance and facilitation of the instructors, the students finally chose two projects. The first project was to improve the current work process of the machine shop on campus by introducing a cellular layout (work cell) to it. The second was to improve the layout of the library on campus to make services more efficient.

In order to assist the students, the instructors developed a diagram (as shown in Figure 2) that showed what the students needed to know from MFG 407. This diagram summarized the relevant topics in facilities planning and material handling and served as a learning guideline for the students.

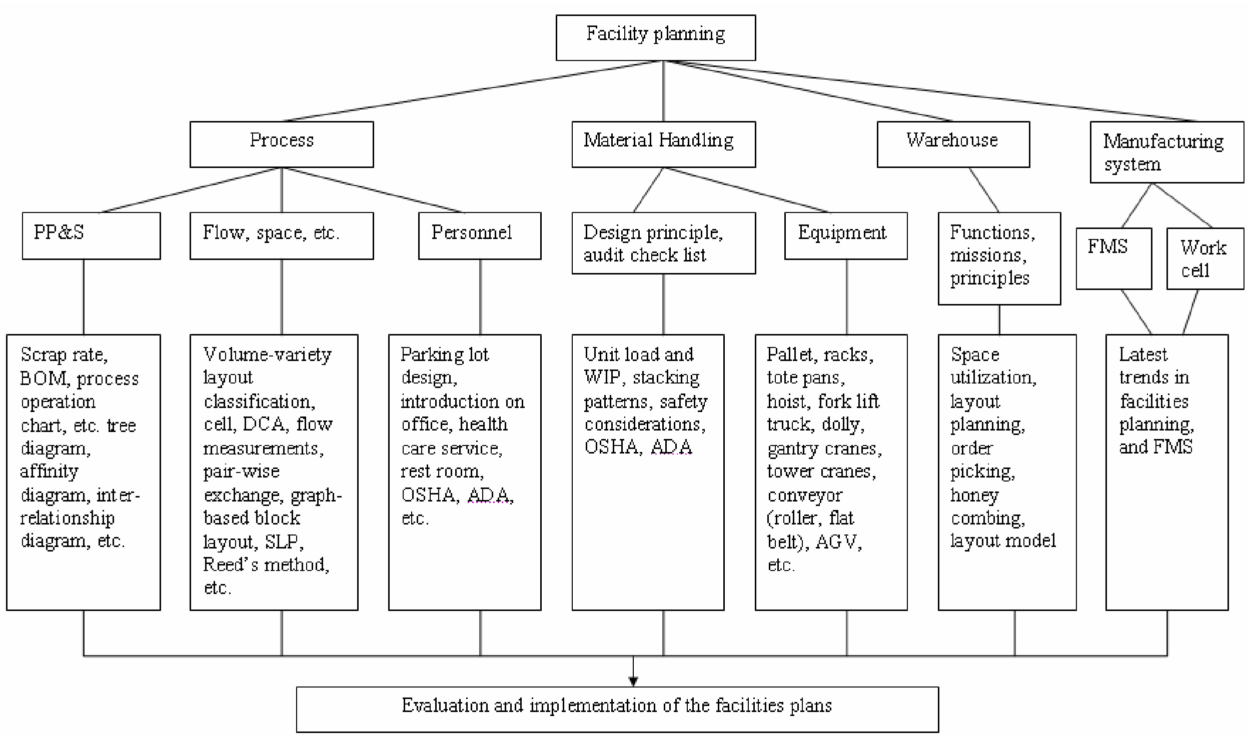


Figure 2. Outline of facilities planning and material handling.

In-class learning with help of multimedia technologies

Besides the conventional methods, such as lectures, group discussions, homework assignments, and exams, multimedia technologies were also widely used in MFG 407. SME (Society of Manufacturing Engineers) video series *Fundamentals of Plant Layout* and various DVD programs that introduced facilities planning and material handling systems were played in the class. These supplementary multi-media materials facilitated students' learning as well as their projects to a considerable extent. The students commented as follows:

- "I found the tape very interesting … and the DVD also valuable."
- "We chose to apply SLP process. Video was very helpful."
- "It showed us how to do our projects since we followed the same simplified SLP process they used."
- "[These materials] told us what to think about in doing our layout."
- "[These materials] were great visual aids."

Enrichment of learning by plant tours

Project-based learning is strongly problem-oriented, and frequently the student projects are motivated by practical industry problems [5]. The students who are in the project-based learning environment really want to listen to the voices from the industry [8]. To further help the students to learn, the instructors organized plant tours to the manufacturing facilities nearby. The on-site visit was regarded as an important part of the course and accounted for 20% of the final exam grade. Before the trip, each student needed to prepare three or more questions related to their projects. During the visit, the students were reminded to pay close attention to the manufacturing processes, facilities layout and material handling systems. After the visit, each student needed to submit an individual report that summarized what was learned from the plant tour. In order to ensure the quality of the report, the instructors provided a report template (as shown in Figure 3), which contained the required items such as summary of the visit, brief introduction of the company, objectives of the visit, production process description, five aha's that may be used in the projects, observations of the facility, suggested action plans, and conclusions.

The plant visit provided a good opportunity for the students to widen and sharpen their eyes, broaden their knowledge and visualize the challenges facing the industry. The trip also helped the students to find useful hints to solve the project problems. Here are some comments from the students:

- "When the classroom goes out into industry and actually tours a plant, concepts are observed and the principles are better understood."
- "I was impressed naturally since this was my first actual detailed look inside a serious manufacturing facility."
- "Seeing more systems in place will help me to understand the comparisons that can be made from plant to plant."
- "It was a real world example of a manufacturing facility. Very beneficial to me."

Report on Site Visit of xxx Factory
(Percentile represents the grading policy)

Summary of the visit (10%)

1. **Brief introduction of the company (10%)**
   1.1 History of the company
   - Start-up
   - Development
   - Future

   1.2 Other things

2. **Objectives of the visit (5%)**
   2.1 Objective of the on-site visit

   2.2 Questions to ask (focused on what MFG 407 talked about)

   2.3 Other things

3. **Production process introduction (flow process drawings are preferred in addition to word description) (25%)**

   3.1 Process 1
   3.2 Process 2
   3.3 Process 3
   3.4 Others

4. **Five aha (may include the answer to your questions, focused on what MFG 407 talked about) (25%)**

   4.1 Aha 1 (What is it? How will it benefit me, my project, the company or our school?)
   4.2 Aha 2 …
   4.3 Aha 3 …
   4.4 Aha 4 …
   4.5 Aha 5 …

5. **Observations (comments) on the company and action plans (15%)**

6. **Conclusions (10%)**

Figure 3. Template for plant tour report.

Project management and assessment

Establishing a culture that stresses student self-management is an essential part for managing PBL [9]. To manage the projects in MFG 407, the students were encouraged to use professional tools, such as Microsoft Project, to schedule their time, allocate workload and control timelines of the project milestones.

For the instructors, the project assessment was an effective tool to monitor the progress of each project. For the students, it was an incentive to improve their self-management. Three checkpoints were used to assess the projects.

The first checkpoint was a written interim report, which accounted for 30% of the project grade. Sometime around the mid-term, the students were asked to submit and present a group-based interim report. The report was required to consist of

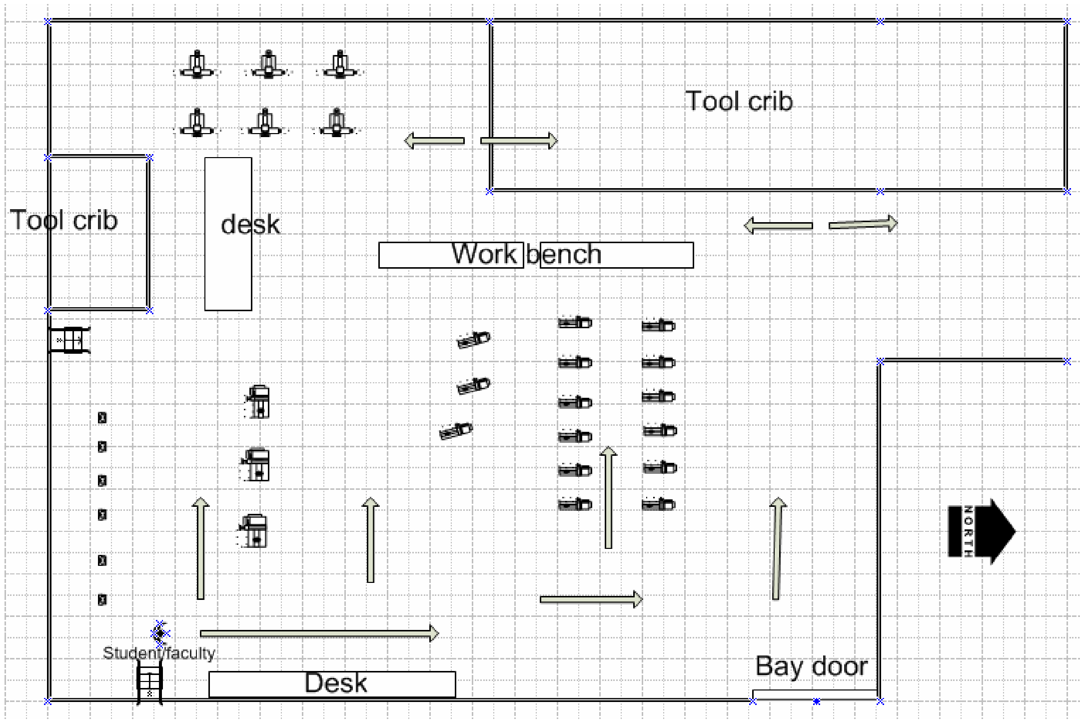
- Problem statement
  - Describe the issue(s)
  - Report the project sponsors' requirements for addressing the issue(s)
- Scope & schedule of the project
  - Itemize the work the project is going to do
  - Balance the responsibilities of the team members
  - Schedule the project (daily work schedule, and workload of each team member)
- Benefits of the project
  - Estimate the benefits of the solution to address the issue(s) in the project (note: quantification will be needed in final report)

The interim report was the first milestone of the project and the guideline for the remaining work. After the student presentations, instructors worked with each student group to adjust and finalize the project scope and schedule. With refined goals and objectives, as well as scope of work and a schedule, the projects went on at full speed.

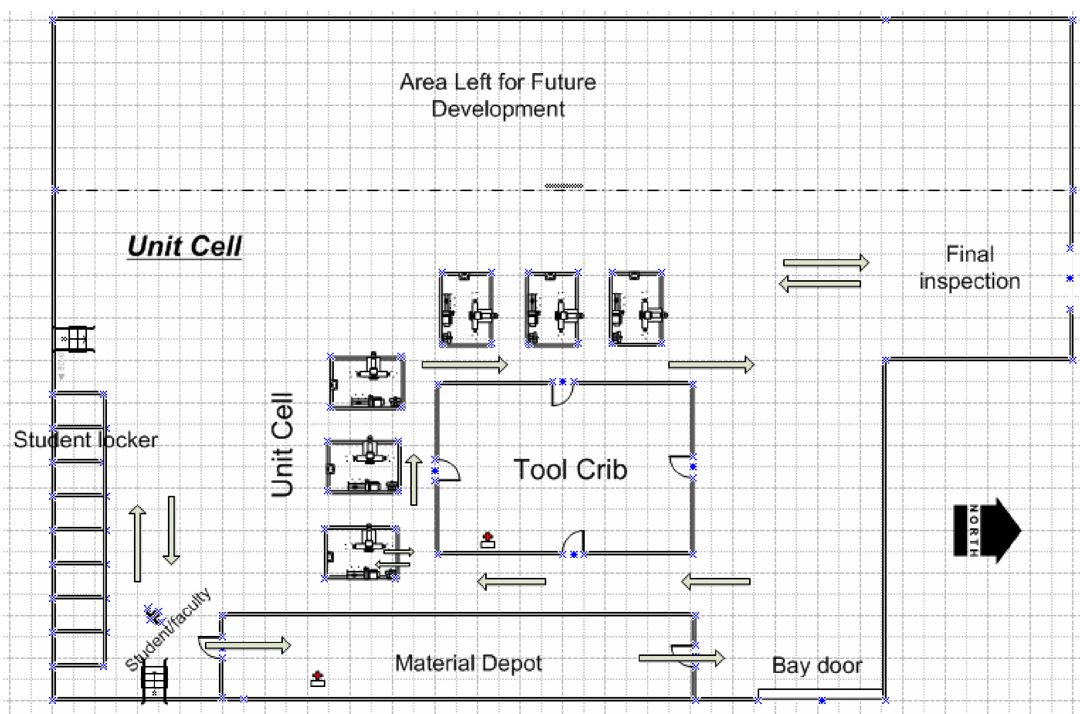
The second checkpoint was a final presentation of the project, which accounted for 30% of the project grade. The presentation was group-based, fifteen minutes long, and was followed by ten minute Q&A. It was required that the final presentations should involve external audiences, including project sponsors, other interested faculty members and students. The presentations were video-taped and archived as a reference for future learning activities. The presentations were graded by the self-performance of each student, including clearness of explanation, answers to the questions, and demonstration skills. The final presentation was the second milestone that led the students to a complete project report.

The last checkpoint was an individual report of the project, which accounted for 40% of the project grade. After the final presentation, each student was asked to submit an individual report. The report was required to follow the documentation guidelines in the textbook [10], and should include cover page, executive summary, table of contents, introduction, body, implementation plan, conclusions, and appendices.

As the core component of the report, layout improvement plans were proposed by the students after they applied fundamental methodologies of facility planning, such as systematic layout planning, direct clustering algorithm, from-to-chart, relationship chart to design. Figure 4 is the example of the project that improved the current work process of the machine shop on campus. The new plan introduced the cellular manufacturing concept, brought in a better material flow, improved the tool and material management, saved machine spaces, and provided much more convenience to the students' machining projects.



(a) Current layout.



(b) Proposed layout.

Figure 4. Current and proposed layouts of the machine shop.

Publication of technical papers based on projects

MFG 407 instructors strongly encouraged the students to publish technical papers based on their projects. Currently, the writing of one technical paper is underway, and the paper will be submitted to 2006 International Conference on Agile Manufacturing. Introducing this approach to the class has three major benefits to the students' academic and professional success:

Firstly, it encourages the students to think deeper into the topics and apply what they have learned to other applications. They were challenged to be innovative and were greatly motivated to read technical papers and books, and to get more knowledge in the related fields. This is an important step for the students to establish life-long learning interests.

Secondly, it provides a gateway for the students who want to continue their education in graduate programs. Reading and writing technical paper is an essential skill for graduate students. Encouraging the students to start this training in their undergraduate program will be helpful to bridge the gap between undergraduate and graduate programs.

Thirdly, to attend and present papers at international conferences provides a good opportunity for the students to demonstrate their academic capabilities and technical skills, gain more confidence in their talents, and network more often with people from industry and academia.

Conclusions

Project-based learning produced encouraging results in MFG 407. The students not only gained theoretical knowledge, hands-on skills, and teamwork skills, but also acquired confidence to meet the challenges in their future professional development in manufacturing areas. Here are some comments from the students about MFG 407:

- "Very beneficial for plant design and related projects. Something I can talk about in an interview."
- "The knowledge that I gained will benefit my thinking processes that have to do with Facilities Layout and Material Handling, as well as my general knowledge base in the Manufacturing subject."
- "With the knowledge gained in the class the group [students] may be able to assist the plant and make it more productive facility."
- "MFG 407 will strengthen my resume and make me a more valuable engineer. All of the concepts are applicable."
- "The material is directly applicable to all sectors of manufacturing. I recommend this course highly [to other students]."

More encouragingly, all the project sponsors have expressed their strong interests in keeping the collaborations with the instructors, and they will provide more project opportunities for the future students.

Industry is looking for engineers and researchers who are not only experts in their own domains, but who are also adept communicators, good team members, and life-long learners. Project-based learning is effective for the professional development of the students. It emphasizes teamwork and close interaction with industry. The instructors will continuously improve this learning environment and explore possibilities to extend the application to other engineering courses.

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